Cruise Report: R/V *Sanna*
2–5 August 2021

The Arctic Observing Network: Renewing Observations at the Davis Strait Gateway

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Technical Report

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ABSTRACT

Oceanic freshwater and heat exchange between the Arctic and North Atlantic provide critical mechanisms through which the Arctic and global climate interact. Arctic fresh water, from riverine input and melting sea ice, flows southward through the Arctic Gateways to the west (Davis Strait) and east (Fram Strait) of Greenland into the regions of the subpolar North Atlantic where the waters that occupy the deep ocean interior are formed. At these sites, strong wintertime storms cool the upper ocean, making these waters dense enough to cause them to sink to depth, effectively communicating this atmospheric forcing into the ocean interior and driving the equator-to-pole transport of heat. Fresh, buoyant Arctic outflow reduces the density of surface waters in these deepwater formation regions, and thus has the potential to slow the sinking and modulate equator-to-pole heat transport. Changes in Arctic outflow also impact broad North Atlantic circulation patterns and circulation off the Labrador coast, with wide-ranging impacts to ecosystems. Conversely, the northward flow of relatively warm Atlantic waters can supply oceanic heat to melt Greenlandic glaciers where they encounter the ocean, thus accelerating the melting of Greenland ice cap. Uncertainty surrounding the role of oceanic heat in accelerating the melt of Greenland's glaciers is one of the largest sources of uncertainty in numerical predictions of future sea level rise. The critical role of Arctic-subpolar heat and freshwater exchange motivates renewed efforts to maintain sustained, persistent, measurements across Davis Strait, capturing exchange between the Arctic and subpolar North Atlantic (Labrador Sea) at a choke point at the southern end of Baffin Bay.

This project renews the integrated observational program at Davis Strait, delivering data to the community and matching ongoing collections at Bering Strait, Utqiagvik, Alaska, and Fram Strait to extend the time series of concurrent measurements across the major Arctic Gateways. The extended timeseries will document changes in freshwater and heat fluxes, and will be combined with numerical modeling to investigate the processes that control variability in the strait and the potential impacts. The backbone system relies on the tested combination of moorings instrumented with sensors to measure ice thickness and motion, ocean currents, temperature and salinity, and biennial ship-based sampling of chemical and biological properties that have successfully delivered core measurements for the past decade. Bottom pressure sensors augment the system to quantify sea surface height gradients, which will support investigations of the primary forcing mechanisms. Integrated marine ecosystem observing includes biogeochemical and marine mammal passive acoustic measurements augmented with tracking of key fish species, and zooplankton and phytoplankton observations. These observations will launch the Davis Strait/Baffin Bay Distributed Biological Observatory (DBO) in Davis Strait, complementing the developing Atlantic DBO that includes transect lines in Fram Strait and Barents Sea, and the existing Pacific DBO in the northern Bering, Chukchi, and Beaufort seas.

1. SCIENCE BACKGROUND

The Arctic freshwater cycle is a longstanding framework for efforts to quantify and understand Arctic change due to its important role in modulating the Arctic energy balance and, further afield, global climate (e.g. *Prowse et al*., 2015; *Carmack et al*., 2016). Freshwater enters the Arctic upper ocean primarily through river discharge, Bering Strait inflow and net precipitation, with the majority exiting about equally though the Canadian Arctic Archipelago (CAA) and Fram Strait (*Serreze et al*., 2006; *Haine et al*., 2015). Because salinity controls Arctic Ocean stratification, this freshwater creates a cold, buoyant layer below the ice-ocean interface that insulates the surface from the warmer, more saline Atlantic waters below, thus modulating sea ice formation and melt and, through this, coupling between the upper ocean and local atmospheric forcing. Freshwater and heat exchange between the Arctic and North Atlantic provide critical mechanisms through which the Arctic and global climate interact. Arctic freshwater discharges through Davis and Fram straits near deepwater formation regions west and east of Greenland, where its buoyancy may act to modulate convective overturning and deepwater formation (e.g., *Karcher et al*., 2005; *Jahn and Holland*, 2013, *Yang et al*., 2016). Changes in Arctic freshwater outflow also modulate the extent and strength of the North Atlantic subpolar gyre, which can have profound impacts on fisheries (*Hatun et al*., 2009), nutrient flux (*Hatun et al*., 2017) and on carbon uptake and storage (*Schuster and Watson*, 2007) in this highly productive region. Additionally, northward penetration of warm Atlantic waters along the Greenland coast may accelerate the melting of marine terminating glaciers (e.g., *Holland et al*., 2008; *Straneo and Heimbach*, 2013; *Myers and Ribergaard*, 2013; *Gladish et al*., 2015), injecting additional fresh water into the system and contributing to sea level rise.

Davis Strait (**Fig. 1**) provides a single site for quantifying both CAA outflow and northward fluxes along the West Greenland slope and shelf that may impact land ice melt. The CAA component of Arctic outflow enters Baffin Bay though four distinct passages (Bellot Strait, Barrow Strait, Hell Gate/Cardigan Strait, and Nares Strait), undergoing numerous transformations along its transit to Davis Strait. By the time they reach Davis Strait, Arctic waters already embody most of the transformation they undergo prior to exerting their influence on the deepwater formation sites in the Labrador Sea. This makes the Strait an ideal site to quantify the variability and structure of the integrated CAA freshwater flux after it has undergone these complex transformations (*Azetsu-Scott et al*., 2012), and just prior to entering the Labrador Sea. Sustained observations at Davis Strait also provide early detection of corrosive Arctic outflow into the subpolar North Atlantic, where it may impact highly productive regions and important commercial fisheries; observations document changes in these chemical states and the marine ecosystem response to ocean acidification (*Azetsu-Scott et al*., 2010; *Hammill et al*., 2018).

2. DAVIS STRAIT ARCTIC GATEWAY OBSERVING SYSTEM

The Davis Strait observing system was established in 2004 to advance understanding of the role of Arctic – sub-Arctic interactions in the climate system by collecting sustained measurements of physical, chemical, and biological variability at one of the primary gateways that connect the Arctic and subpolar oceans. Efforts began as a collaboration between researchers at the University of Washington's Applied Physics Laboratory and Department of Fisheries and Oceans, Canada at Bedford Institute of Oceanography, but has grown to include researchers from the Greenland Institute of Natural Resources, Greenland Climate Institute, Technical University of Denmark, University of Alberta, and University of Colorado, Boulder. The project is a component of the NSF Arctic Observing and Atlantic Meridional Overturning Networks, and the international Arctic-Subarctic Ocean Flux (ASOF) program, Global Ocean Ship-Based Hydrographic Investigations Program (GO-SHIP), Global Ocean Acidification Observing Network (GOA-ON), Synoptic Arctic Survey (SAS), Arctic Monitoring Assessment Programme (AMAP), and OceanSITES system.

The 2020 R/V *Dana* cruise restarteds the observing system after a three-year hiatus in the moored measurements and a five-year gap in chemical and biological sampling. The renewed system employs an array of 12 moorings across Davis Strait, deployed at the locations occupied by the previous arrays. The mooring array provides estimates of mass, heat, freshwater and ice transports, and marine mammal presence. Bottom pressure recorders deployed along the western and eastern flanks of Davis Strait and in northern Baffin Bay augment the mooring array by providing estimates of barotropic transport through the Strait, constraining interpretation of remotely sensed altimetry and gravity measurements and allowing an investigation of how sea surface height differences between the Arctic and Baffin Bay modulate exchange through Davis Strait. An extensive program of biennial chemical sampling in Davis Strait, northern Labrador Sea, and southern Baffin Bay quantifies changes in nutrient loads, carbon transport and acidification, while also providing data to distinguish freshwater constituents in the Davis outflow. These biogeochemical signals integrate changes in the large-scale circulation (e.g., the ratio of Pacific to Atlantic waters, carbon transport, and pH changes). The new system includes a significantly expanded suite of biological and biogeochemical measurements, including dissolved organic matter (DOM), particulate organic carbon (POC), chlorophyll, zooplankton biomass and community structure, phytoplankton productivity, fish larvae and census (from the Canadian Ocean Tracking Network), seabird observations, and marine mammal presence.

3. OBJECTIVES

Deploy the Davis Strait moorings BI-2 and BI-4, which the team was unable to accomplish during the 2020 R/V *Dana* cruise due to an inability to secure permission to enter Nunavut waters.

4. CRUISE NARRATIVE

Times in UTC unless otherwise noted.

2 August

Meet R/V *Sanna* in Ilulissat. Prepare instruments and set up lab.

3 August

Depart Ilulissat, transiting out of Disko Bay and across Davis Strait.

4 August

Arrive off the Baffin coast. Deploy shelf moorings BI-2 and BI-4. Begin return transit to Greenland.

5 August

Arrive Sisimiut.

5. MOORING OPERATIONS

Instrument start times were set to 00:00Z 4 August 2021 so that all instruments were logging prior to arrival at the deployment sites.

R/V *Sanna* deployed BI-2 and BI-4 off the Baffin coast (**Fig. 1** and **Table 1**). BI-2 (**Fig. 2**) consisted of a SBE-37 CT sensor and data logger situated a few meters off the bottom, with an ICECAT package suspended above, roughly 30 m from the sea surface. BI-4 (**Fig. 3**) was similarly configured, but with an ADCP in between the bottom-mounted sensors and the ICECAT.

Moorings were deployed through the stern A-frame using the R/V *Sanna* large trawling winch. Each operation started by deploying the ICECAT float and cable by hand, after which the rest of the mooring was handled using the A-frame and winch. The A-frame provided sufficient clearance to accommodate all lifts. Winch control was coarse, sometimes leading to rougher handling of instruments than would be ideal.

Table 1. Davis Strait moorings deployed from R/V *Sanna* 2021.

	Lat (N)	Lon (W)	Bottom (m)	Notes
BI2	66° 39.534'	61° 10.118'	79 m	Deployed 20:54Z, 4 Aug 2021
BI4	66° 38.827'	61° 13.370'	152 m	Deployed 19:00Z, 4 Aug 2021

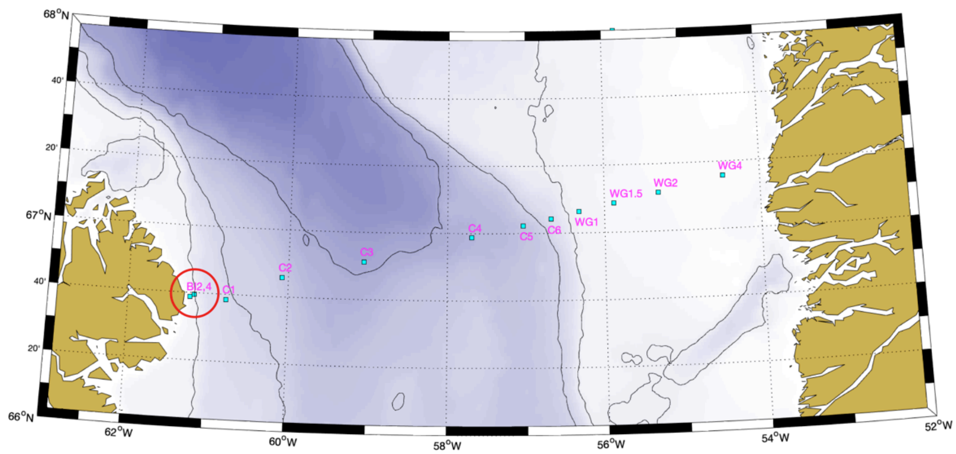

Figure 1. *Davis Strait mooring sites (light blue squares). Only the two moorings in the red circle (BI2 and BI4) were deployed in 2021.*

6. SCIENCE TEAM

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7. COVID MITIGATION

The 2021 Davis Strait cruise was undertaken during a period of loosening COVID-19 restrictions. Lee tested before departing Seattle and before departing Denmark (as required by the Greenlandic government). Masks were worn in transit but not aboard R/V *Sanna*.

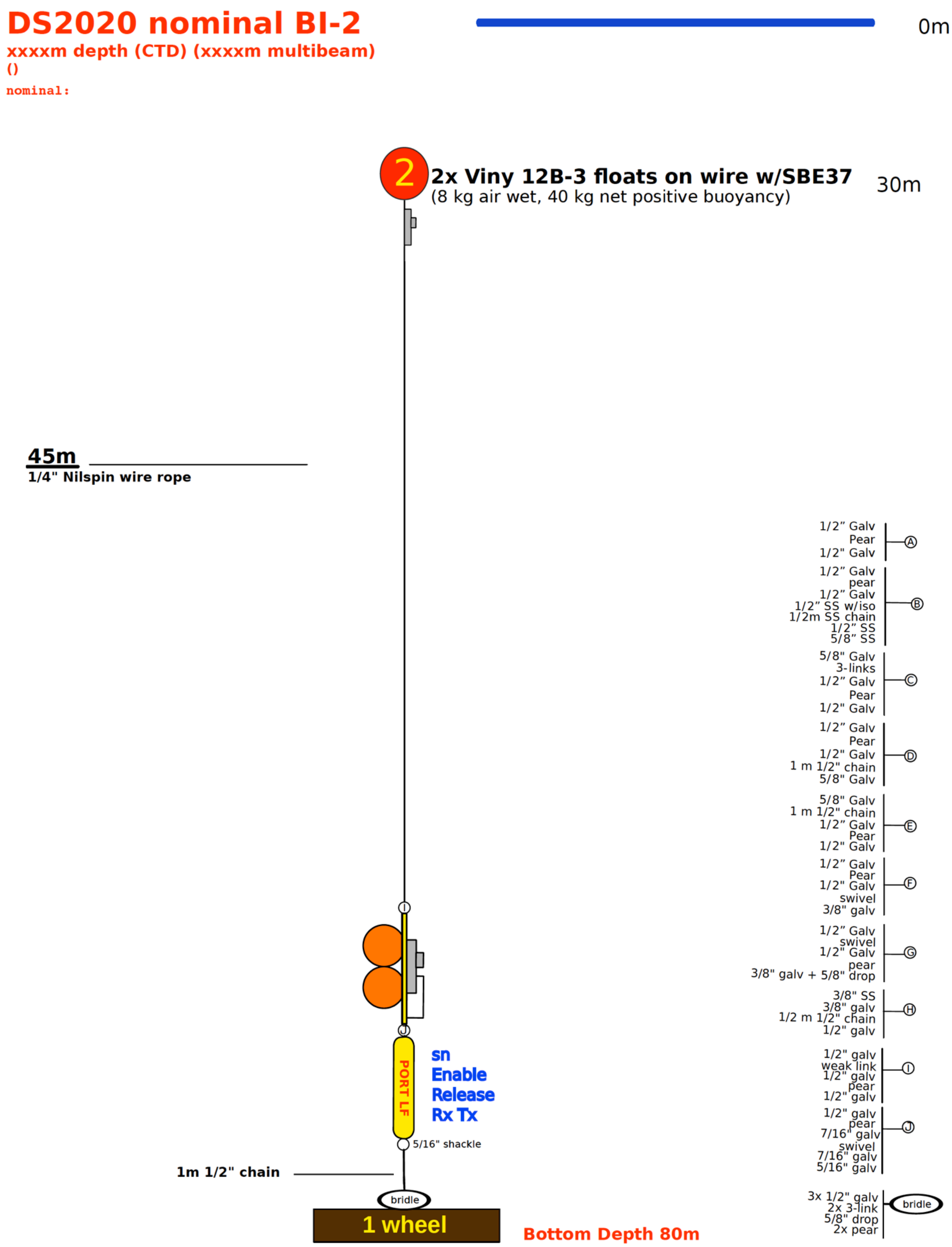

Figure 2. *BI2 Mooring diagram (Baffin Shelf).*

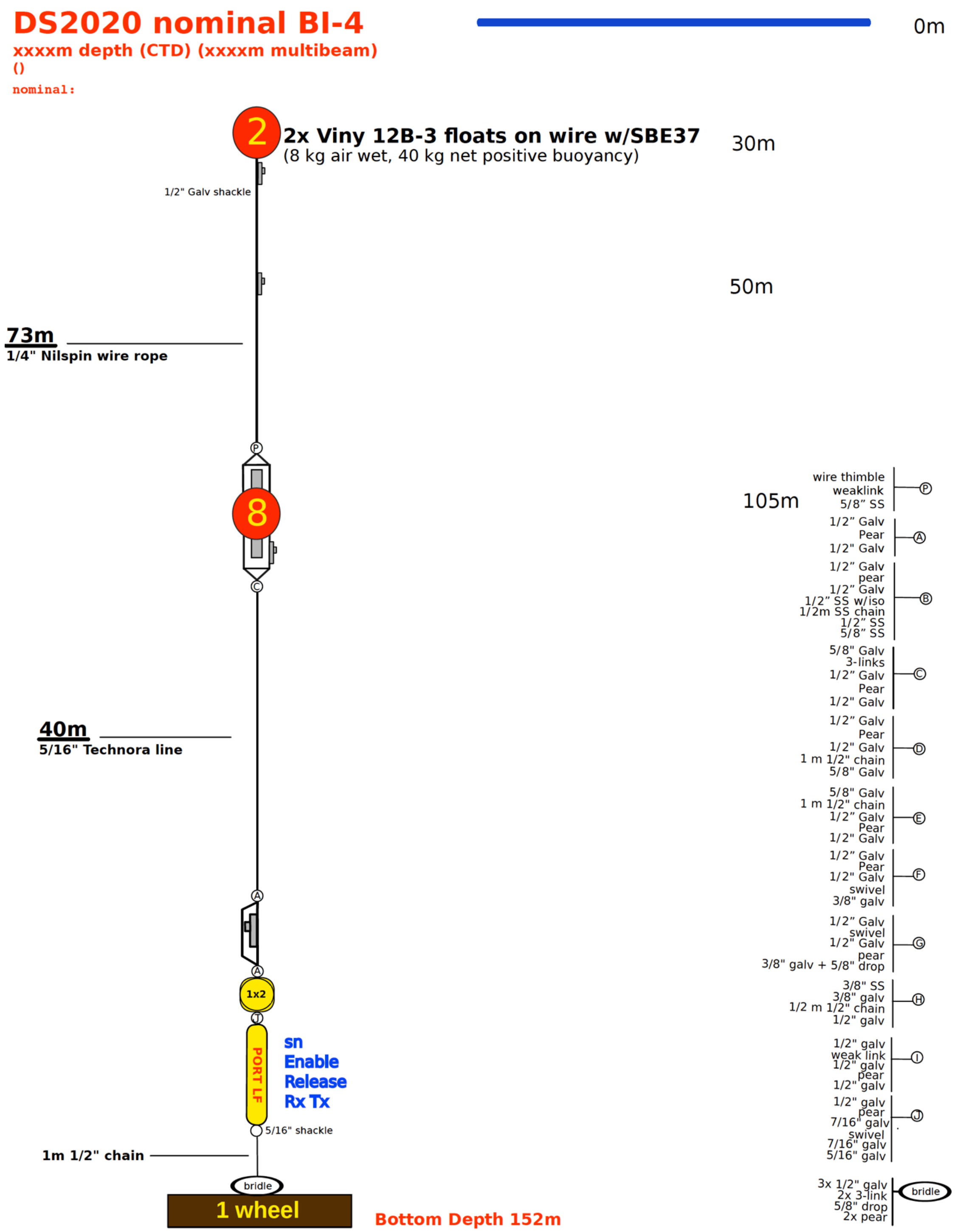

Figure 3. *BI4 Mooring diagram (Baffin Shelf).*

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